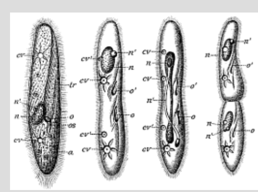
Unit 3B: Cell Division & Heredity

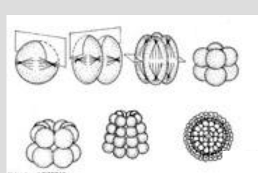
Part 1

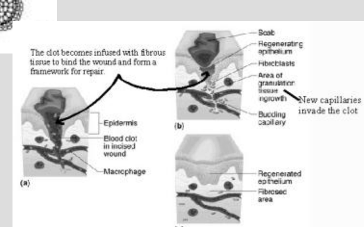
The Cell Cycle & Mitosis

Cell Division

- Why divide?
  - Asexual reproduction
  - Growth
  - Repair & Renewal

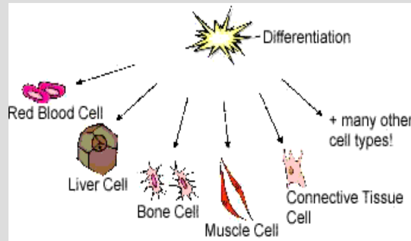


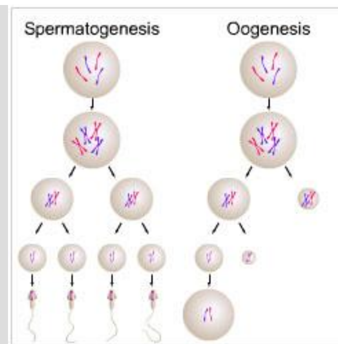




2 Cell Types

- Somatic Cells
  - Produced by MITOSIS
  - Diploid (2n)
    - 2 sets of chromosomes
- Reproductive Cells
  - Produced by MEIOSIS
  - Haploid (n)
    - 1 set of chromosomes





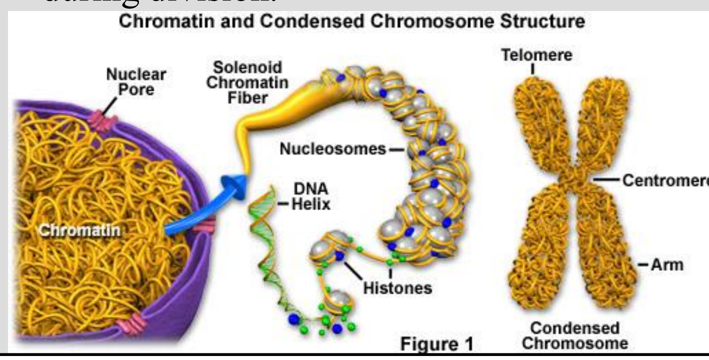
Mitosis

- Goal: To create a GENETICALLY IDENTICAL copy of a cell.
  - The entire genome is duplicated
  - The cytoplasm is partitioned “equally”
  - 1 cell becomes 2 cells, 2 cells become 4 cells…

DNA Organization

- Chromatin: All of an organism's DNA in an uncondensed, loose mass.

  Seen during times of normal functions, not during division.



DNA Organization

- Chromosomes: All of an organism's DNA in condensed, tight bunches.
  - Seen during times of cell division.
- Centromere: Area where a chromosome is constricted. Location that chromatids attach to each other.

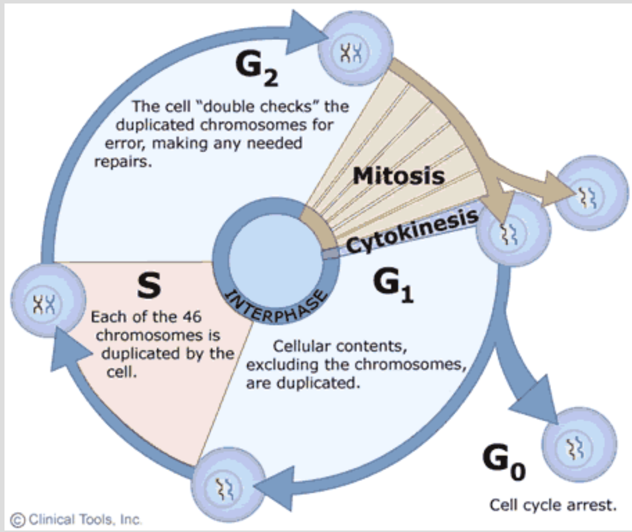
Cell Division Terminology

- These words can be confusing, be sure to know the differences!
  - Chromosome:
    - Condensed DNA before duplication
    - Condensed DNA after duplication & also after separation by mitosis
  - Chromatid (sister chromatid):
    - Half of a duplicated chromosome
    - A duplicated chromosome has 2 chromatids

The Cell Cycle

- This is a CYCLE: Knowing where in the cycle a cell is helps for remembering what comes next and what is required for it to happen.
  - Interphase: Growth, DNA synthesis, preparation for division.
  - Mitotic phase (M phase)
    - Mitosis: Partitioning of DNA into each cell
    - Cytokinesis: Division of cytoplasm

The Cell Cycle



Interphase

- **G1 Phase** – Cell grows and produces proteins, extra organelles.
  - Regulated at the G1 checkpoint by proteins called **cyclins**.
  - If passed, cell usually continues the rest of the cycle.
  - If not passed, cell enters G0 phase. The cell essentially exits the division phase and can "try again later" or will not divide for its duration.
    - Nerve Cells - Muscle cells

Interphase

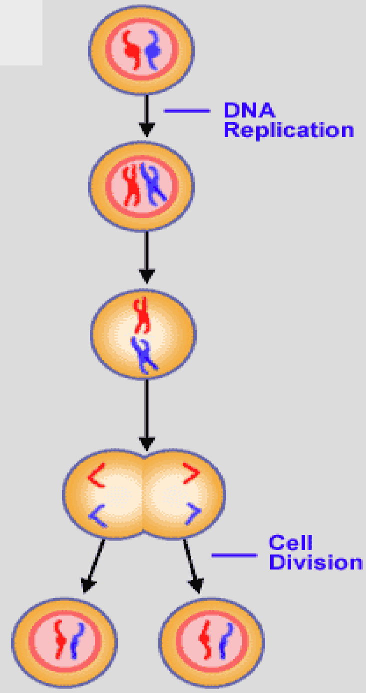
- S Phase – "Synthesis" Phase
  - DNA is duplicated
  - Point at which each single chromosome becomes a chromosome with 2 chromatids. The chromatids are identical.
  - Chromatids are "linked" at their centromeres.

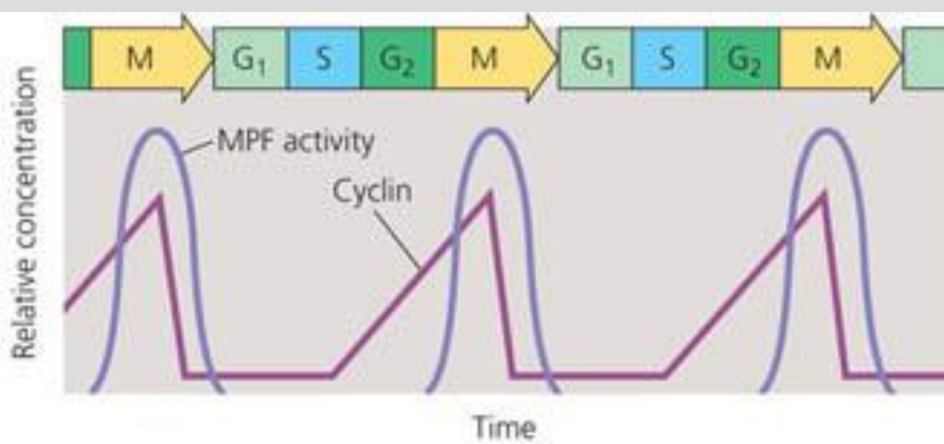
Interphase

- G2 Phase – Cell grows and produces proteins, extra organelles.
  - Regulated at the G2 checkpoint by proteins called **cyclins**.
  - Specific regulating factor is called **MPF**
    - M-phase Promoting Factor
- Remember: DNA has doubled!

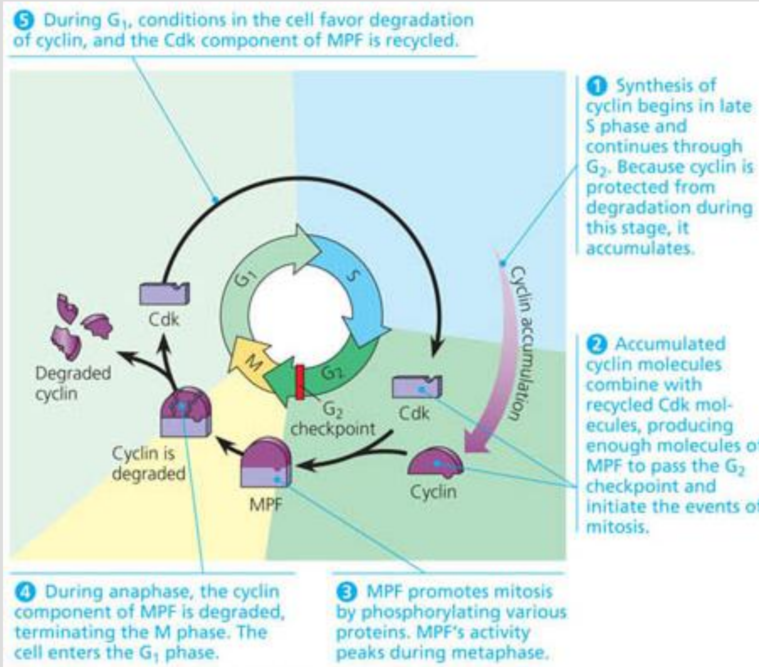
M Phase =

Mitosis &
Cytokinesis





(a) Fluctuation of MPF activity and cyclin concentration during the cell cycle



(b) Molecular mechanisms that help regulate the cell cycle

Loss of Control

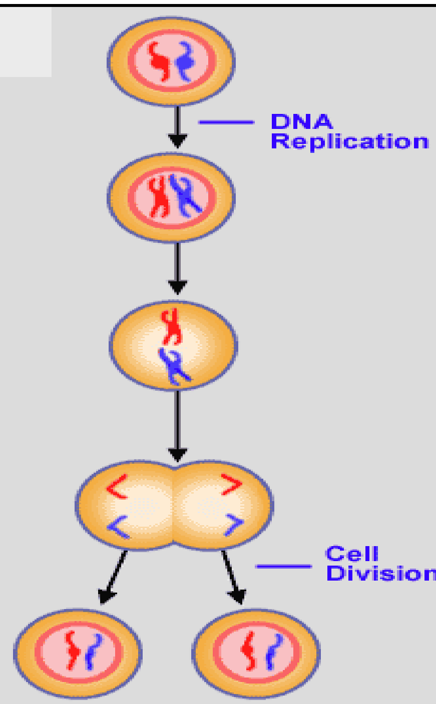
- Cancer cells: Cells that have overcome the control of the cell cycle.
- Example: **Gene Amplification** of Cyclin D
  - Leads to overproduction of Cyclin D, causing the cells to constantly divide.
  - Possible reasons why DNA is *continuously* transcribed & translated (expressed):
    - "Stress"?
    - Carcinogenic chemicals?

Part 2

Meiosis

I. Meiosis vs. Mitosis

Mitosis = makes cells with the SAME NUMBER and TYPE of chromosomes as the original cell.



I. Meiosis vs. Mitosis

Sexual Reproduction

In the resulting organism:

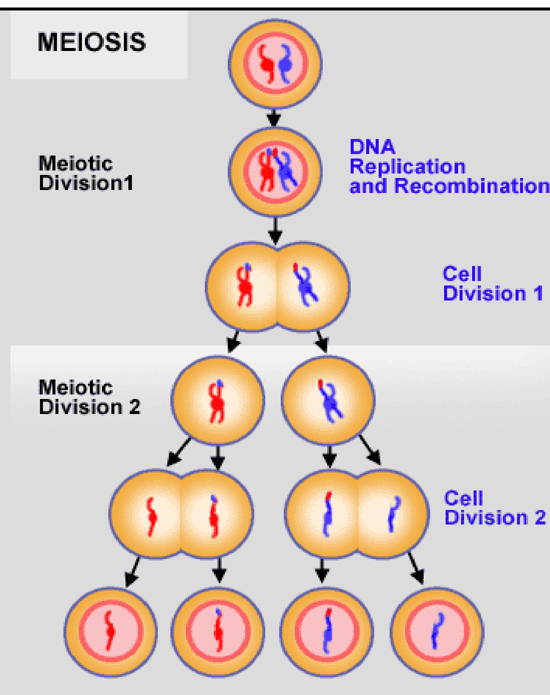
- Half of the DNA comes from one parent ("male")

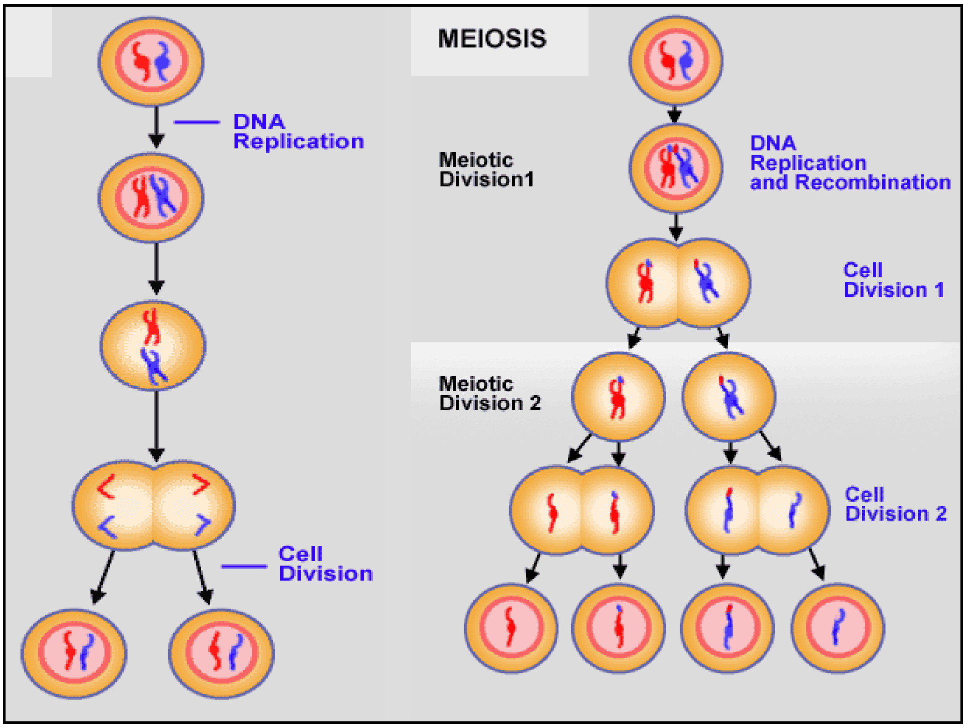
- Other half of DNA comes from the other parent ("female")

I. Meiosis vs. Mitosis

Meiosis = Makes cells with HALF THE NUMBER of chromosomes as the original cell.

Genetic variation also results.



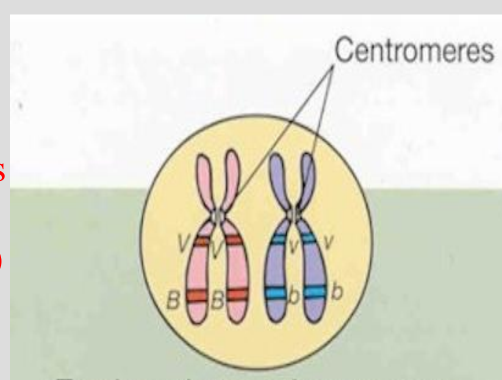


VI. Meiosis

A. Meiosis I

a. DNA is copied

b. Cell starts out diploid (certain cells travel to the gonads to become sex cells)

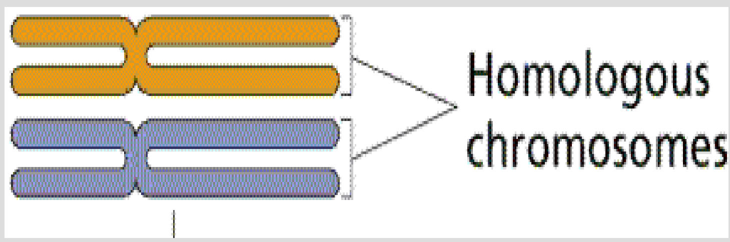


VI. Meiosis

A. Meiosis I

c. Homologous chromosomes match up:

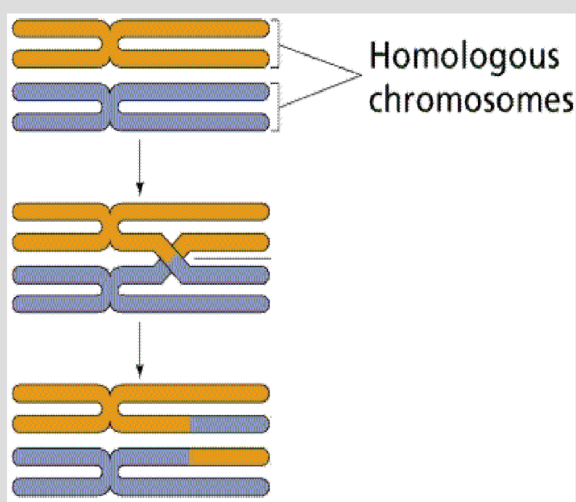
1 from “mom”, 1 from “dad”



VI. Meiosis

A. Meiosis I

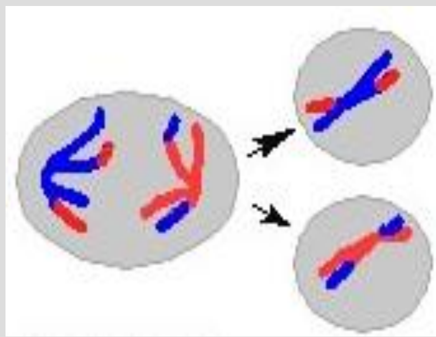
d. Crossing over = Exchanging pieces of DNA.



VI. Meiosis

A. Meiosis I

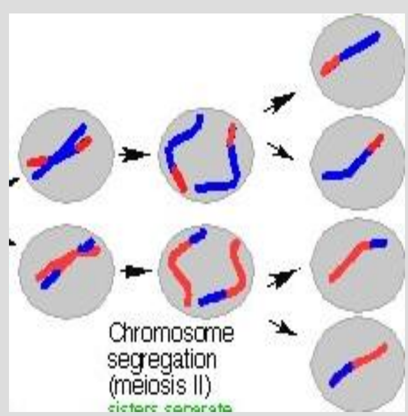
e. Homologous chromosomes pulled apart and end up in 2 different cells.



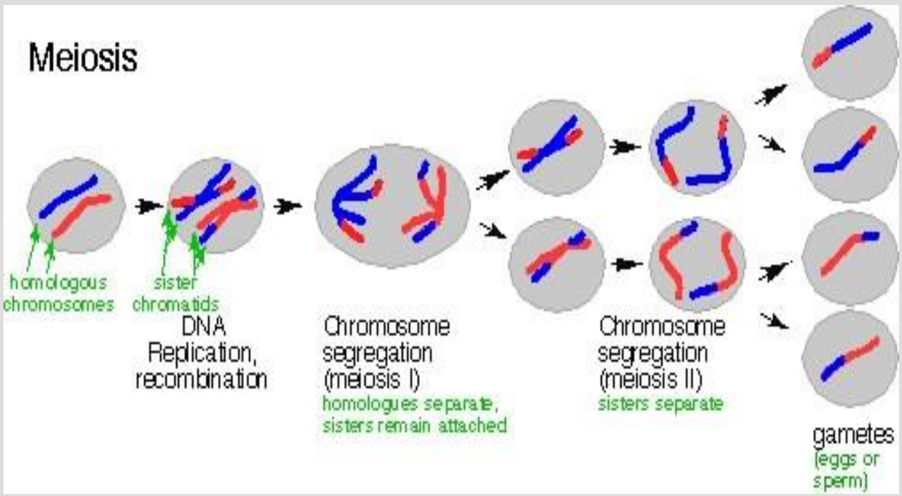
VI. Meiosis

B. Meiosis II

a. In each of the 2 new cells, the chromotids are pulled apart and end up in 2 more new cells. Result is 4 **haploid**, **genetically distinct** cells.



Summary of Meiosis



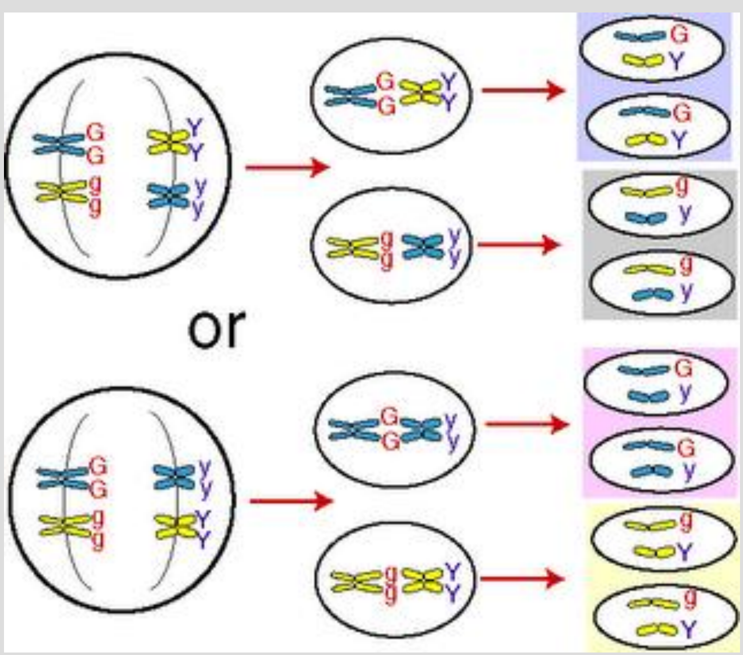
Unit 3B: Cell Division & Heredity

Part 3 - Patterns of Heredity

Laws Governing Outcomes

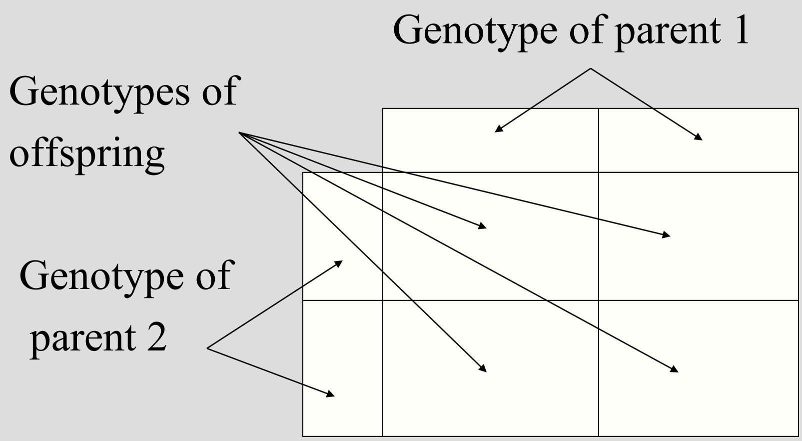
Law of Segregation: Alleles separate from each other during **meiosis**.

Law of Independent Assortment:
Gametes then combine differently during **fertilization**.



Punnett Squares

A. Diagrams for predicting results of any cross.



Single Trait Cross

A. A cross for 1 trait.
   1. Hair color ONLY

Single Trait Cross

Genotype of parent 1

T T

Genotype of parent 2

t t

	T	T
t		
t		

XI. Single Trait Cross

Results: All 4 combinations are the same.

<u>Results vary depending on parents!</u>

	T	T
t	T t	T t
t	T t	T t

XI. Monohybrid Cross

F1 Cross: Cross 2 of the “kids”.

Results: 1:2:1 Genotypic Ratio

3:1 Phenotypic Ratio

	T	t
T	T T	T t
t	T t	t t

XI. Monohybrid Cross

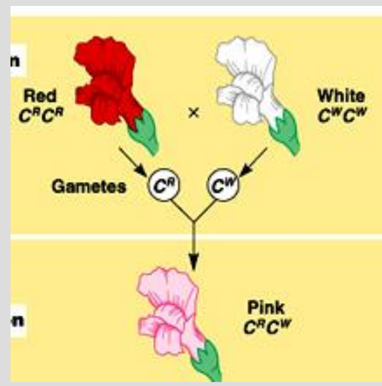
- RULE: According to Mendel’s Laws, A **monohybrid** cross of F1 will ALWAYS result in 3:1 <u>p ratio</u> and 1:2:1 <u>g ratio</u>.
- If not… something else is influencing
  - Alternate types of dominance

XII. Dominant/Recessive??

A. Simple rules of dominance/recessive don't always hold true.

1. Incomplete dominance:

Both alleles present = Intermediate



XII. Dominant/Recessive??

2. Codominance:

Both alleles present = Both appear

Brown & White both dominant = both colors appear

XII. Dominant/Recessive??

3. Multiple alleles:

More than 2 alleles for 1 gene

Blood Groups

Allele combination	Blood type
I^AI^A or I^AI^O	A
I^BI^B or I^BI^O	B
I^AI^B	AB
I^OI^O	O

I^O is sometimes written as "i"

ii = O, I^Ai = A, etc.

Sex Chromosomes

2. 44 Autosomes & 2 Sex chromosomes

a. Male: 46,XY

b. Female: 46,XX

Sex Chromosomes

3. Sperm = X or Y   4. Egg = X only

Female

Male

	X	X	
X	**XX**	**XX**	**50% female**
Y	**XY**	**XY**	**50% male**

Sex-Linked Genes

1. Found on the sex chromosomes, X or Y.
2. Y-linked traits = "maleness" mostly
3. X-linked traits = many traits
   - Colorblindness

Sex-Linked Genes

4. Males = Y X
   a. All X-linked traits will be expressed in males.
      Only 1 X chromosome, so either YES or NO!

5. Females = X X
   a. If trait is dominant, it will be expressed if 1 copy is present.
   b. If trait is recessive, it will be expressed if present on BOTH X chromosomes.

XIII. Two Trait Cross

A. A cross that looks at 2 traits.
   1. R = right handed r = left handed

   2. D = Dimples d = no dimples

XII. Dihybrid Cross

Genotype of parent 1 = **R r D d**

Genotype of parent 2 = **R r D d**

1. **Figure out the combinations for each parents' gametes.**

XII. Dihybrid Cross

Genotype of parent 1 = **R r D d**

FIRST

R r X D d

R D

XII. Dihybrid Cross

Genotype of parent 1 = **R r D d**

OUTSIDE

R **r** **X** **D** **d**

R d

XII. Dihybrid Cross

Genotype of parent 1 = **R r D d**

INSIDE

R **r** **X** **D** **d**

r D

XII. Dihybrid Cross

Genotype of parent 1 = **R r D d**

LAST

R **r** **X** **D** **d**

r d

XII. Dihybrid Cross

Genotype of parent 1 = **R r D d**

Gamete combinations =

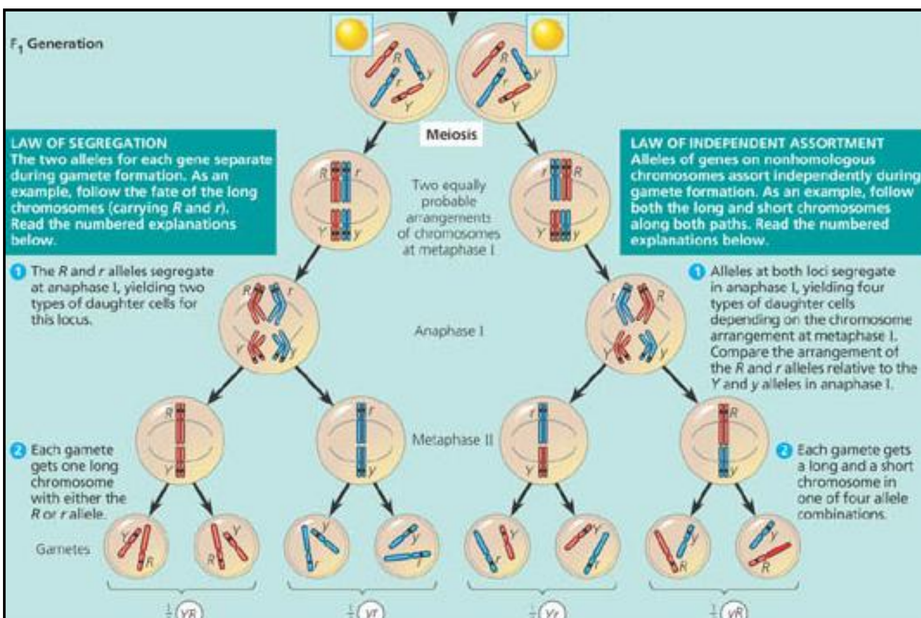
R D **R d** **r D** **r d**

XII. Dihybrid Cross

Genotype of parent 2 = **R r D d**

Same genotype, same gamete combinations =

R D   R d   r D   r d



XII. Dihybrid Cross

2. Make a Punnett square: 16 possibilities

XII. Dihybrid Cross

3. Parents' possible gametes

	R D	**R d**	**r D**	**r d**
R D				
R d				
r D				
r d				

XII. Dihybrid Cross

	R D	R d	r D	r d
R D	RRDD	RRDd	RrDD	RrDd
R d	RRDd	RRdd	RrDd	Rrdd
r D	RrDD	RrDd	rrDD	rrDd
r d	RrDd	Rrdd	rrDd	rrdd

XII. Dihybrid Cross

5. Results:

The probability of having a child with dimples and being left-handed?

3/16 = r r D D
r r D d
r r d D

Out of 16, 3 should be left handed and have dimples.

XII. Dihybrid Cross

6. Independent Assortment

a. New combo's were made

b. Traits didn't affect each other

c. Gene for right hand/left hand **independent** from gene for dimples… why?

XII. Dihybrid Cross

6. Independent Assortment

d. On different chromosomes!

* Different genes *can* assort independently of each other if they are on **different** chromosomes.

XII. Dihybrid Cross

Phenotypic Ratio is always:
9:3:3:1

If not… something else is going on… Alternate type of dominance, sex linked trait…

Probability

A. Punnett squares can get too large if we look at more than 2 traits. Using rules of probability can be used when asking a specific question.

1. Rule of multiplication
    a. signaled by the word "AND"
    - what's the probability I will have a boy **and** he will have blue eyes?

Probability

1. Rule of multiplication

boy = XY   girl = XX   blue eyes = gg

GgXX (mom) x GgXY (dad)

Do one trait at a time, then multiply both.

Blue eyes = gg… what's the prob. Of gg? ¼

Boy = XY… what's the prob. of XY? ½

¼ x ½ = 1/8 prob. of blue eyed boy.

Probability

2. Rule of addition

a. Signaled by the word "OR"

simplest example: what's the prob. Of getting a boy OR a girl?

XX x XY

prob. of a girl = ½   prob of a boy = ½

½ + ½ = 1 (100%)

Obviously!

Statistical Analysis

- Data can be used to test if some alternate form of inheritance is acting, or if some type of influence (environment, another gene, etc.) is acting.
- Observed & expected values will be statistically different.

Statistical Analysis

- Null hypothesis = **There is no** statistically significant difference between observed data and expected data.
- Alternate hypothesis = **There is** a statistically significant difference between observed data and expected data.

Statistical Analysis

- Methods: Chi square analysis
- $X^2 = \Sigma [(o – e)^2 / e)]$
- Σ = sum   o = observed # individuals
- e = expected # individuals

Statistical Analysis

- Example Problem

Round is dominant to wrinkled in pea seeds.

A cross produced 722 round seeds and 278 wrinkled seeds.

Is this data significant enough to verify the expected inheritance pattern?

Statistical Analysis

phenotype	# observed (o)	# expected (e)	(o – e)	$(o - e)^2$	$(o - e)^2 / e$
green					
albino					

Statistical Analysis

Step 1: Calculate Chi Square

- $X^2 = \Sigma [(o - e)^2 / e]$ = _____________

Statistical Analysis

Step 2: Determine degrees of freedom (df)

- The # phenotypes minus 1
- df = ___________

Statistical Analysis

Step 3: Find critical value at .05 p value

Probability (p)	Degrees of Freedom (df)				
	1	2	3	4	5
.05	3.84	5.99	7.82	9.49	11.1

Statistical Analysis

Step 4: Use critical values to analyze results

- IF Chi square value is > or equal to critical value, the **null** hypothesis is **REJECTED**.

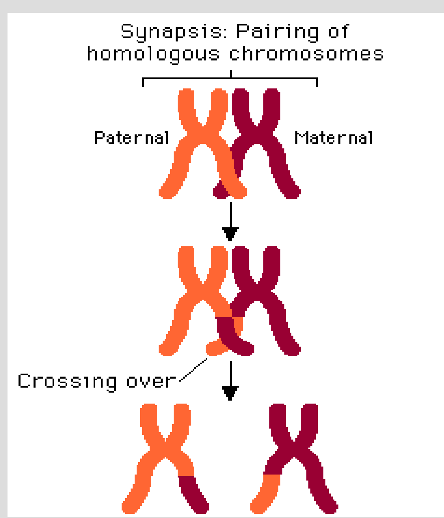
- Meaning… the data are statistically different from expected values.

- IF Chi square value is < the critical value, the **null** hypothesis is **ACCEPTED**.

-Meaning… The data are not statistically different from expected values.

A Closer Look at Meiosis

- Crossing over: Parts of a homologous chromosome cross to the other homologous chromosome.



Recombination

- Case 1: Recombination of genes that are on different chromosomes (Unlinked).

YyRr (yellow, round) x yyrr (green, wrinkled)

¼ YyRr (yellow, round) ¼ yyrr (green, wrinkled

¼ Yyrr (yellow, wrinkled) ¼ yyRr(green,round)

½ Parental Pheno. ½ Recombinant Pheno.

Recombination

- Case 1: Recombination of genes that are on different chromosomes (Unlinked).
- 50% recombinant offspring is the EXPECTED value for unlinked genes.

Recombination

- Case 2: Recombination of genes that are on the same chromosome (Linked).
- Any number less than 50% means the genes must be on the same chromosome.
- The LOWER the number of recombinants = the CLOSER the genes are to each other.

Recombination

- Equation for calculating recombination Frequencies & distance the genes are from each other.

Freq. R = # recombinants/ total offspring

Other Weird Patterns…

- Mitochondria & Chloroplast assort completely randomly into new cells.
- Mitochondrial DNA in animals transmitted only from the Ovum – female egg

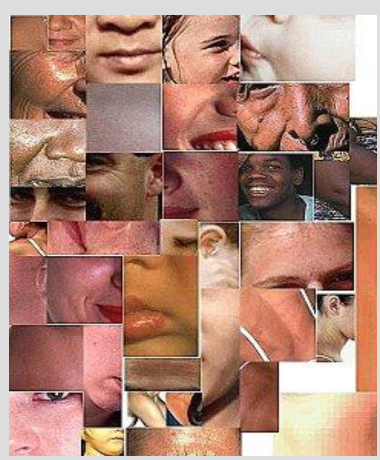
  (Thanks again for everything mom!)

  (Thanks for half a nucleus dad!)

Influences on Genes

A. **Polygenic Traits:** Traits that are controlled by more than 1 gene.

   1. **Eye color**
   2. **Skin color**



Influences on Genes

B. The Environment

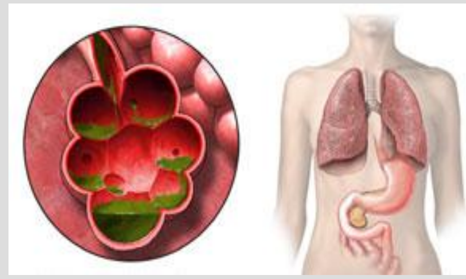
1. Plant height

2. Human weight

Human Disorders

- Many ethical, medical & social concerns surround human genetic disorders.
  - Fetal testing for disorders
  - Economic impacts on families
  - Gene therapy for disorders

Human Disorders



1. Recessive disorders
   a. Cystic Fibrosis

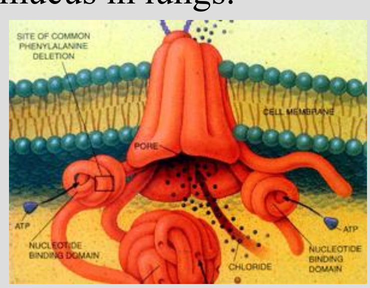
   Symptoms: Excess mucus in lungs, digestive problems, prone to infections.

   Most Affected: Northern European ancestry.

Human Disorders

Cause: Deletion of 3 bases = no phenylalanine.
CFTR protein malfunctions = mucus builds up.

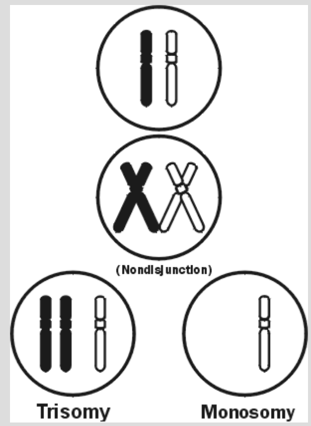
Treatment: Nebulizer = Thins mucus in lungs.



Chromosome Disorders

Nondisjunction: Homologous chromosomes don’t separate during meiosis.

1. Incorrect number of chromosomes.



Chromosome Disorders

Down Syndrome

3 copies of chromosome 21